Streamlined Methods for Deriving Site-specific Numeric Nutrient Criteria in Montana-DRAFT 8/28/2013

1.0 Background and Rationale

Numeric nutrient criteria have been proposed for all major and several minor ecoregions in Montana (Suplee and Watson, 2013). Suplee and Watson (2013) also include a limited number of site specific criteria, and it has been acknowledged that the Department will need to develop other site-specific nutrient criteria going forward. A criteria development approach using empirical or process-based models (e.g., QUAL2K) has been outlined in Appendix A of the Department's draft guidance document "*Nutrient Standards Implementation Guidance"*. The process described in the guidance document is, however, data intensive. There will likely be streams which warrant site-specific numeric nutrient criteria but for which a smaller dataset and less rigorous analysis can be used; this paper outlines a simplified, streamlined approach for doing this.

This simplified approach was motivated by observations stemming from the application of the Department's methodology for assessing stream eutrophication (Suplee and Sada de Suplee, 2011). Using those methods, some streams have been found to support a healthy stream ecology and are in compliance with the biologically-based assessment parameters (e.g., levels of benthic chlorophyll *a*, macroinvertebrate HBI metric), but show exceedences of one or both of the nutrients (N, P) recommended as criteria. Site-specific numeric nutrient criteria are likely to be appropriate in these situations.

This document is organized as follows:

1. The basic concept and approach is presented (**Section 2.0**)

2. Assessment of biological health and minimum dataset requirements are provided (**Section 3.0**).

3. A case study example is given (**Section 4.0**)

2.0 Site-specific Methods

This section outlines the streamlined approach to deriving site-specific nutrient criteria for streams.

2.1 Principal Site-specific Methods

Nutrient concentration data from reference sites have been compiled for each ecoregion (Suplee and Watson, 2013). Data from dose-response studies (nutrient concentration as dose, impact to beneficial use as response) applicable to each ecoregion have also been compiled. Each of these data types provide concentration ranges within which this streamlined site-specific criteria method can operate. In applying this method, two scenarios will be encountered.

Scenario 1: **Figure 2-1** illustrates how information from ecoregionally-applicable reference sites can be used. It is assumed here that a stream assessment (per Suplee and Sada de Suplee, 2011) has already been carried out and has shown that a particular stream's biological condition supports all uses, i.e., no detrimental eutrophication effects have been observed. In **Figure 2-1**, the Department's recommended criterion (black dot with X) falls within the reference distribution of the ecoregion's reference-site data (median dataset[1]; Suplee and Watson, 2013). This occurs in a number of ecoregions, for example for TP in the Middle Rockies, due to the fact that dose-response studies were the primary consideration in setting the criteria. What the data show us is that there are reference sites which routinely manifest nutrient concentrations higher than the regional criterion; therefore, there is a range of concentrations beyond the recommended nutrient criterion that may still be protective within the ecoregion.

In scenario 1, If an *assessed* stream meets the Department's biological expectations and manifests a nutrient concentration falling between the Department criterion and the 95th percentile of the ecoregional reference dataset (within the dashed arrow, **Figure 2-1**), then the assessed stream is eligible for a site-specific criterion. The stream's new criterion should be established at the 80th percentile of the stream's nutrient dataset[2]. This criterion can then be recommended to the Board of Environmental Review for adoption as a site-specific nutrient standard during a subsequent triennial review.

[1] The median dataset must be used for this analysis and is available from the Department. In the median dataset, within any given ecoregion, nutrient concentrations from each site were first reduced to a median, and then descriptive statistics were calculated for the population of site medians. For an example, see Table 3-1B in Suplee and Watson (2013).

[2] Assuming the assessment methodology in Suplee and Sada de Suplee (2011) remains the same, the stream in question would, in the future, be assessed using the binomial test for streams considered compliant with the nutrient criteria (i.e., null hypothesis is "stream compliant with nutrient criteria"). Due to the allowable exceedence rate (20%) and the gray zone (15%) established in the binomial test, a site-specific nutrient criterion set at the 80th percentile of the site's existing dataset will consistently PASS the binomial in the future (assuming the stream's nutrient conditions are unchanged). The T-test would also be PASS.

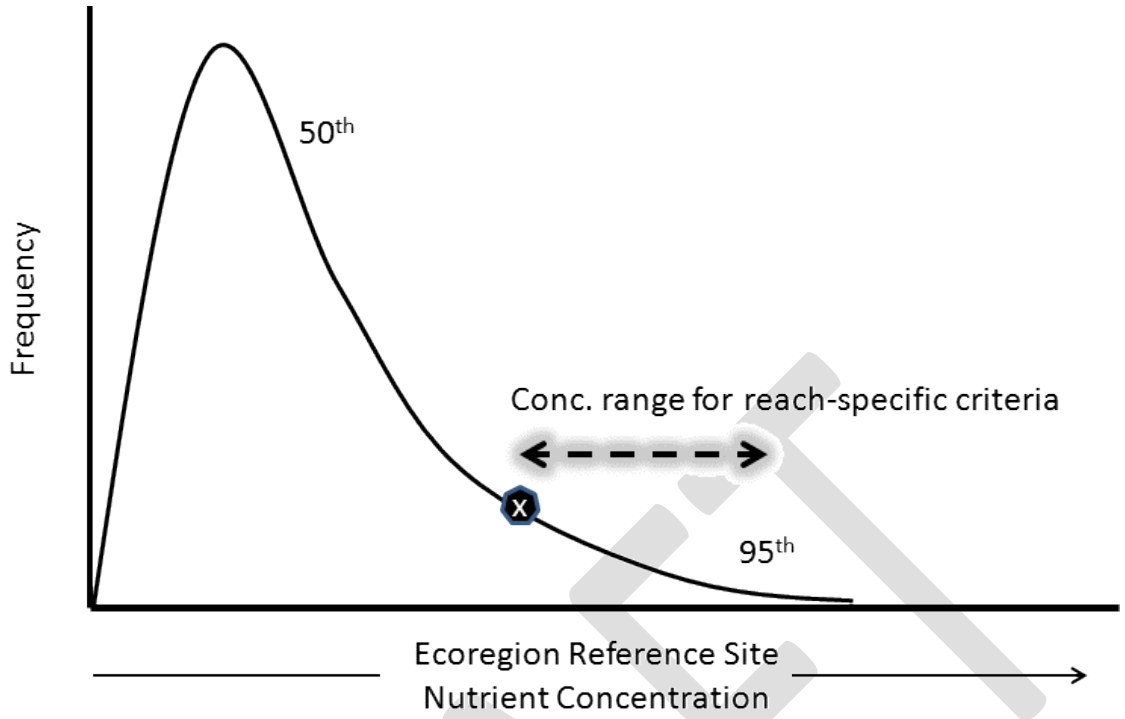

Figure 2-1. Scenario 1. Candidate site-specific nutrient criteria may fall between the ecoregional criterion recommended by the Department (black dot with X) and the 95th percentile of the applicable reference distribution (dashed arrow). The reference distribution used must be the median dataset from Suplee and Watson (2013) or its equivalent update. This method only applies to streams that demonstrate good biological health and full support of beneficial uses using assessment methods in Suplee and Sada de Suplee (2011).

Scenario 2: In other cases, the criteria recommended by the Department are very near to or beyond the 95th percentile of the ecoregional reference distribution. In these cases, the approach shown in **Figure 2-1** will not work and an alternative approach is illustrated in **Figure 2-2**. For each level III ecoregion, Suplee and Watson (2013) have provided in each concluding paragraph a range of concentrations from the dose-response studies they reviewed. The dose-response studies most applicable to the ecoregion in question (not the broader range of generally-applicable studies) will provide the concentration range within which site-specific criteria can be identified.

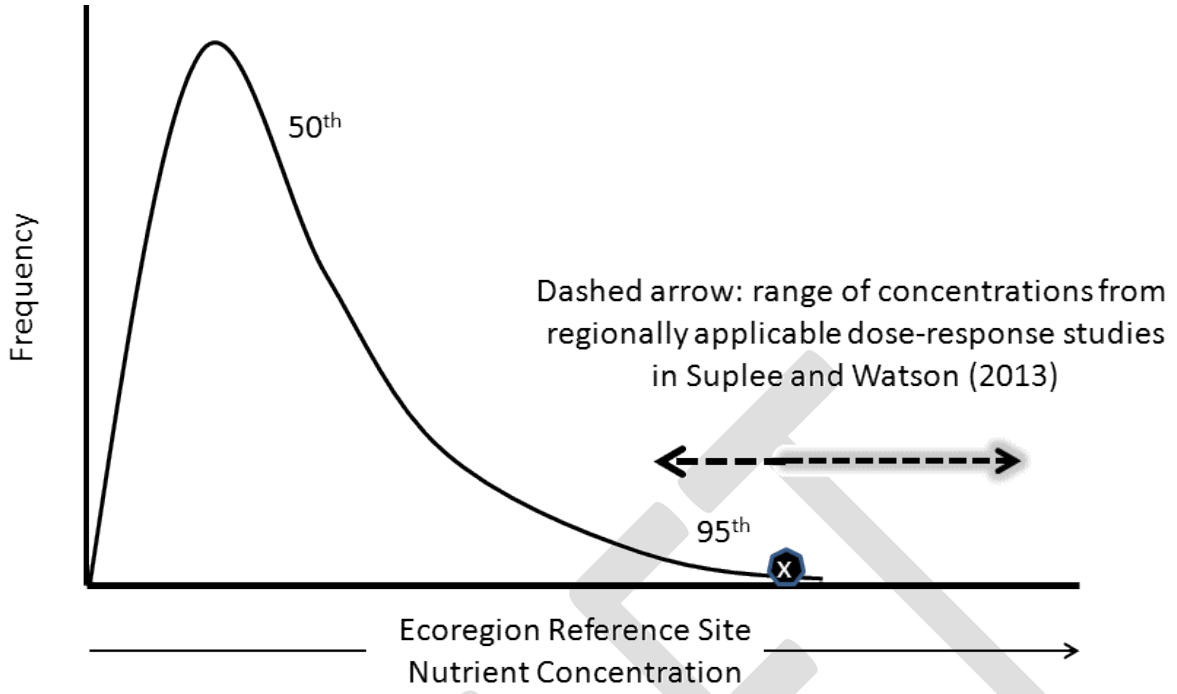

Figure 2-2. Scenario 2. Site-specific criteria derivation method for cases where a Department-recommended criterion is near or above the 95th percentile of the ecoregional reference distribution. Candidate site-specific nutrient criteria fall between the criterion recommended by the Department (black dot with X) and the upper range of the values from the dose-response studies specifically applicable to the ecoregion in question (dashed arrow with gray fringe). The dose-response studies must be from Suplee and Watson (2013) or equivalent updates.

If an *assessed* stream meets the Department's biological expectations but manifests a nutrient concentration above the Department's criterion, and that criterion is near or above the 95th percentile of the ecoregional reference dataset, then the range of concentrations from the applicable dose-response studies can be reviewed. If the assessed stream's nutrient concentration at the 80th percentile falls within the range of the regionally-applicable dose-response studies, then that concentration can be used as a site-specific criterion. This criterion can then be recommended to the Board of Environmental Review to be adopted as a site-specific nutrient standard.

2.1 Other Methods

Recent work in the scientific literature provides a means to develop site-specific criteria on a stream-by-stream basis; the method was specifically developed for western regions of the United States (Olson and Hawkins, 2013). This method uses a geospatially-driven model that considers major environmental factors within a watershed that influence nutrient concentrations in streams (geology, precipitation, soil bulk density, etc.). The Department is using this method to help derive nutrient criteria for an area of the state with few or no reference sites and what appears to be naturally-elevated phosphorus

concentrations. It should be pointed out that the method is not for use in the plains region of Montana (Olson and Hawkins, 2013).

The Department will consider results provided by others that have used the Olson and Hawkins (2013) method. (Again, this is predicated on the assumption that full biological support is shown in the stream.) However, results from this model will need to be reviewed by the Department on a case-by-case basis. If approved, they can be recommended to the Board of Environmental Review for adoption as site-specific standards.

In general, streams whose nutrient concentrations fall outside of the defined ranges in **Figures 2-1** and **2-2** are not eligible for this streamlined approach. Rather, methods outlined in Appendix A of the Department's draft guidance document "*Nutrient Standards Implementation Guidance"* should be used. There may also be cases where an upstream level IV ecoregion with naturally high nutrient concentrations is influencing the stream in question, and the reach-specific methods in Section 4.0 of Suplee and Watson (2013) may be applicable.

3.0 Confirmation of Biological Health, and Minimum Dataset

This section addresses the minimum requirements needed to assert that the biological health of the stream fully supports beneficial uses.

3.1 Assessment of the Biological Health of the Stream

Assessment methods outlined in Suplee and Sada de Suplee (2011) will be used. That assessment methodology is designed to provide a minimum dataset by which eutrophication-based impacts to beneficial stream uses can be assessed. Data types include:

1. A minimum nutrient dataset (usually 12-13 independent samples)

2. Benthic chlorophyll *a* samples

3. Periphyton samples for taxonomic identification and biological metrics

4. Aquatic insect (macroinvertebrate) samples for taxonomic identification and biological metrics

Data are to be collected during the defined growing season for the ecoregion in question. Given that the minimum data requirements have been met for all data types (nutrients and biological), a stream assessment may come to a scenario that lends itself to site-specific nutrient criteria. **Table 3-1** shows cases where site-specific criteria are likely valid; the table shows just two of the many potential outcomes in the final status determination of a stream assessment (Suplee and Sada de Suplee, 2011).

Table 3-1. Data assessment outcomes which lend themselves to site-specific nutrient criteria.

Scenario(s)	Scenario subclass	Nutrient Binomial Test	Nutrient T-test	Benthic Algae	Diatom Increaser Taxa-Probability of Impairment	Macroinvertebrate HBI Score
7,8	7/8a	FAIL	FAIL	≤125 mg Chla/m2 or ≤35 g AFDW/m2	≤51%	>4
7,8	7/8b	FAIL	FAIL	≤125 mg Chla/m2 or ≤35 g AFDW/m2	≤51%	≤4

In **Table 3-1**, which applies to western Montana streams, it has been found that an assessed stream's nutrients are elevated and fail both statistical tests (the binomial, which looks as the proportion of observations above the criterion, and the t-test, which addresses the dataset average and the presence of high outliers). Note however that the biological signals are all or nearly all acceptable; benthic algal biomass is below the threshold, diatom metrics (where applicable) show a low probability of nutrient impairment, and the macroinvertebrate-based HBI metric is acceptable since it is < 4 (at least for scenario subclass 7/8b), meaning water quality is very good (Hilsenhoff, 1987). Of the two cases shown, subclass 7/8a is less clear due to the elevated HBI score and additional data collection would be warranted before site-specific criteria are developed. For prairie streams, see scenarios 5 and 7, part 2 (Suplee and Sada de Suplee, 2011) as they are equivalent to those in **Table 3-1**.

3.2 Dataset Minimum

All data collection must follow Department SOPs (e.g., DEQ, 2011a; DEQ, 2011b; DEQ, 2012). Dataset minimums for a stream assessment are defined in Suplee and Sada de Suplee (2011). For the purposes of developing site-specific nutrient criteria via the process in this document, the dataset needs to have been collected for three years (though not necessarily contiguously) for all of the data types required in Suplee and Sada de Suplee (2011). For western Montana streams, this would be nutrients, benthic chlorophyll *a*, diatoms (where applicable), and macroinvertebrates. If the dataset minimums to complete a stream assessment were achieved after just two years of data collection (which is common), a complete third year of data must be collected as well.

The complete, three-year dataset must be taken through the assessment data matrix. In some cases the additional year may change the initial outcome and it may result that the stream no longer comes to the scenarios shown in **Table 3-1** and site-specific criteria are not warranted. However if the assessed stream again arrives to the scenarios in **Table 3-1**, site-specific nutrient criteria are likely warranted and the approaches outlined in **Section 2.0** may be applied.

3.3 Consideration of the Other Nutrient

Where a site-specific criterion is warranted for a nutrient elevated above the Department's ecoregion-based criteria, consideration must be given to the other nutrient in the stream (N vs. P, and vise-versa). For example, a stream manifesting good biological health but elevated P concentrations may very likely be N limited, and should be maintained so. If N limitation were alleviated, there is a high likelihood that the biological health of the stream would be impacted. The Redfield ratio (Redfield, 1958) will be used as a general guide for establishing which nutrient limits (ratio < 6, N limits; ratio > 10, P limits) and for establishing the final concentration of the other nutrient.

What the updated criterion for the non-elevated nutrient should be needs to be determined on a case-by-case basis in conjunction with the Department. A first-cut approximation would be roughly 75% of the established ecoregional criterion concentration.

In some cases, *both* N and P will be elevated above the Department's recommended criteria. In such cases each nutrient should be evaluated per methods in **Section 2.0** and it may result that site-specific criteria for both N and P will be higher than the Department's values. In such cases factors other than nutrients are likely limiting nutrient effects in the stream.

4.0 Case-study Example

The following is a case which lends itself to site-specific nutrient criteria.

4.1 Data Summary for Stream X (in Middle Rockies Ecoregion)

***Years of data*:** 3 (2004, 2011, 2012)

Number of Nutrient Samples: 12-14 (meets minimum)

Average Total Phosphorus (TP) Concentration: 35 µg/L

Average Total Nitrogen (TN) Concentration: 40 µg/L

Benthic Chlorophyll a Samples: 3 (each comprised of 11 sub-replicates) (meets minimum)

Diatom Metric Samples: Not applicable (Department has no validated diatom-based metrics for the Middle Rockies ecoregion at this time)

Macroinvertebrates Samples: 3 (meets minimum)

4.2 The Assessment of Stream X

The applicable criteria for the Middle Rockies are 30 µg TP/L and 300 µg TN/L (Suplee and Watson, 2013). Data for stream X were evaluated and TN was found to be quite low (average = 40 µg/L), well below the recommended ecoregional criterion of 300 µg/L. However TP averaged 35 µg/L and was

above the ecoregional criterion of 30 µg/L. All biological indicators were found to be acceptable; the data fit scenario subclass7/8b in **Table 3-1**. In additional, other aspects of the data were considered. The macroinvertebrate O/E scores were reviewed to see if they were above 1.0[3] (none were). The benthic chlorophyll *a* concentrations were not only below the threshold they were very low (<< 50 mg Chl*a*/m^2), as was algal AFDM. Nitrate concentrations were also evaluated, and all concentrations were very low.

4.2 Site-specific Criteria Derivation for Stream X using the Streamlined Approach

The Department's recommended criterion for the Middle Rockies ecoregion (where stream X is located) is 30 µg TP/L; this value matches the 82nd percentile of the Middle Rockies' reference data (median dataset; Suplee and Watson, 2013). The TP concentration at the 80th percentile of stream X's dataset is 42 µg TP/L, a concentration equal to the 89th percentile in the Middle Rockies reference dataset. Therefore, stream X fits scenario 1 (**Figure 2-1**) because its site-specific TP value (42 µg/L) falls between the Department's recommended criterion and the 95th percentile of the Middle Rockies reference dataset. Stream X's new criterion (42 µg TP/L) is not too far above the Department's criterion, so a large reduction in the stream's TN criterion is not warranted. But it is prudent to set the TN lower than 300, to 250 µg TN/L (which is at the 97th percentile of the Middle Rockies reference distribution). This maintains a Redfield ratio of < 6 which should help maintain N limitation. **The site specific criteria would be 42 µg TP/L and 250 µg TN/L, applicable during the growing season for the Middle Rockies (July1-Sept 30).**

5.0 References

DEQ (Department of Environmental Quality), 2011a. Sample Collection and Laboratory Analysis of Chlorophyll-*a* Standards Operating Procedure. WQPBWQM-011 Version 6.0, *Available at: http://deq.mt.gov/wqinfo/qaprogram/sops.mcpx*

DEQ (Department of Environmental Quality), 2011b. Periphyton Standard Operating Procedure. WQPBWQM-010, *Available at*: *http://deq.mt.gov/wqinfo/qaprogram/sops.mcpx*

DEQ (Department of Environmental Quality), 2012. Sample Collection, Sorting, Taxonomic Identification, and Analysis of Benthic Macroinvertebrate Communities Standard Operating Procedure. WQPBWQM-009 Revision 3, Available at: *http://deq.mt.gov/wqinfo/qaprogram/sops.mcpx*

Hilsenhoff, W. L. 1987. An Improved Biotic Index of Organic Stream Pollution. *Great Lakes Entomologist.* 20(1): 31-39.

[3] O/E scores decline from an ideal score of 1.0 due to impacts from a variety of stressors (excess sediment, heavy metals, elevated temperatures, etc.). However it is not uncommon to see scores > 1.0. These indicate the stream has more species of macroinvertebrates than the model is expecting to see for the region. Essentially, slightly elevated nutrient levels have led to a less austere environment and more species can exist than is normally seen. For this reason O/E scores > 1.0 can be indicative of nutrient enrichment above reference. When nutrient enrichment becomes excessive, O/E scores again drop below 1.

Olson, J.R., and C.P. Hawkins. 2013. Developing Site-specific Nutrient Criteria from Empirical Models. *Freshwater Science* 32(3): 719-740.

Redfield, A. C. 1958. The biological control of chemical factors in the environment. Am. Sci. 46: 205-221.

Suplee, M.W., and R. Sada de Suplee, 2011. Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nitrogen and Phosphorus Levels. Helena, MT: Montana Department of Environmental Quality, 70 p. *Available at:* http://deq.mt.gov/wqinfo/qaprogram/sops.mcpx

Suplee, M.W. and V. Watson, 2013. Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers: Update 1. Helena, MT: Montana Department of Environmental Quality, 125 p. *Available at:* http://deq.mt.gov/wqinfo/standards/NumericNutrientCriteria.mcpx